REMARKS

The Amendments

The specification is amended to delete the articles which were attached as Appendices A-E and, instead, to reference the articles at the appropriate parts of the specification. The material from the Appendix articles is not essential material to the claimed invention and, therefore, its incorporation by reference is not improper. The specification is also amended to refer to the provisional applications from which this application claims priority; the priority claim having been previously made. The specification is further amended to add a Brief Description of the Drawings. The amendments do not narrow the scope of the claims and/or are not made for reasons related to patentability.

New dependent claims fully supported by the disclosure are added; see, e.g., page 2, lines 16-19; page 3, lines 14-18; page 14, lines 17-26, and the JNCS article cited thereat; pages 20-21; and page 22, line 22, to page 23, line 2. The amendments do not narrow the scope of the claims and/or were not made for reasons related to patentability. The amendments should not be interpreted as an acquiescence to any objection or rejection made in this application.

The Objection to the Drawings

Applicants are submitting new formal drawings herewith. However, the drawings have not been modified as to substance, despite the objections in the Office Action, for the following reasons. The features of the invention specified in the claims which the Office Action alleges must be included in the drawings are not the type of features amenable to and customarily included in drawings. The feature of operating the waveguides is not a claimed feature to begin with. Further, this is a method step rather than a physical feature of invention. Method steps are not normally included as drawing features. Additionally, one of ordinary skill in the art would well understand how to operate the optical devices of applicants' invention given their structure and description throughout the specification without the need of a drawing. As to the "modifying the wavelength" step, this is again a method step and not a physical feature of the invention. As recited in claim 12, the method is

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effected by heating. This feature is not amenable to being included as a drawing element; further, one of ordinary skill in the art does not require a drawing to understand this feature of the invention.

Accordingly, it is urged that the objections to the drawings be withdrawn and the attached formal drawings be accepted.

The Objection to the Specification

A Brief Description of the Drawings has been added to the specification to address the objection. A separate Detailed Description of the Invention is not necessary since such is contained within the specification as a whole. It is noted that the preferred arrangement of the specification recited in the Office Action is merely a suggestion, not a requirement. The objection should be withdrawn.

The Rejections under 35 U.S.C. §112, second paragraph

The claims are rejected based on the allegation that the claims omit certain essential elements of the invention. Applicants respectfully disagree and traverse the several rejections made on this basis.

It is alleged that the claims 1-7 do not recite the location/position of the waveguide with respect to the substrate. But independent claim 1 expressly recites "waveguides defined by channels in the substrate." The plain meaning of this is clear and is made even more clear when read in light of the disclosure. That is the waveguides are connected in solid-state fashion with the substrate as channels therein and are differentiated from the substrate by a higher index of refraction; see, e.g., Paper D of the Appendices, Figure 1, page 21; and, page 2, lines 10-22, of the specification. The claims do recite the relationship of the substrate and waveguides and are proper.

It is alleged that the claims 8-15 do not recite steps for preparing an optical device or modifying the wavelength of the waveguides. This rejection is not understood because the independent claims 8 and 12 are explicitly directed to the steps for preparing an optical device and modifying the wavelength of the waveguides, respectively. Claim 8 recites the steps of providing the active and passive regions together and providing the waveguide therein. This provides an optical device (see also the discussion in the next paragraph). Claim 12 makes

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clear that the step of heating modifies the wavelength of the waveguides. How this works is described at page 14 of the specification but it is not necessary or desired to recite such in the claims. The claims recite the necessary step and the specification supports why this is so. Accordingly, the claims do recite the allegedly omitted steps and are proper.

It is alleged that claims 1-15 fail to provide "any waveguide or laser structure to consider as an optical device." However, all of the claims clearly recite the presence of at least one waveguide. The presence of a waveguide alone is sufficient to define an optical device since a waveguide transmits light and thus is a "device" which has an "optical" effect. The optical device term is a broad term here. Thus, for example, the specification makes clear that the optical device term encompasses mere waveguides, lasers, laser amplifiers and similar devices, for example; see, e.g., page 2, lines 10-12; page 3, lines 10-12; and, page 3, lines 15-18. As for the claims directed to lasers, the invention is directed primarily to the waveguide aspect of the laser. One of ordinary skill in the art – particularly in light of the extensive disclosure in the specification (see all the Appendices) – is fully aware of what other elements are used to provide a laser. It is not improper to have claims reciting a device with a combination of elements wherein only one element is specified by the claims and the others are generally included in manners known in the art.

For the above reasons, applicants respectfully submit that the instant claims – and the new claims – are proper under 35 U.S.C. §112 and the rejections should be withdrawn.

The Rejection under 35 U.S.C. §102

The rejection of claims 1-15 under 35 U.S.C. §102, as being anticipated by Bendett (U.S. Patent No. 6,330,388) is respectfully traversed.

Initially, it is pointed out that Bendett is not prior art to the instant application under 35 U.S.C. §102(e) or any other section of 35 U.S.C. §102. The Bendett patent and the instant application have the same effective filing dates based on the same two provisional applications. Because they have the same date and not a prior date, Bendett is not prior art.

The Bendett patent and the instant application do not claim the same patentable invention. The instant claims are directed to an optical device having two or more waveguides. The Bendett claims are directed to laser components which may have a plurality of laser cavities but which also require a ferrule for laser output and optic fiber attachment

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and at least one optic fiber; compare claim 40 of Bendett. Applicants' claims do not require these additional components.
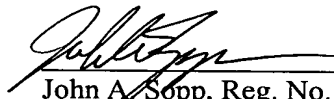
In any event, the rejection under 35 U.S.C. §102 must be withdrawn because Bendett is not prior art.

It is submitted that the claims are in condition for allowance. However, the Examiner is kindly invited to contact the undersigned to discuss any unresolved matters.

Please note that no marked-up version is provided as paragraphs were replaced and new claims were added. Therefore, no marked-up version is necessary.

The Commissioner is hereby authorized to charge any fees associated with this response or credit any overpayment to Deposit Account No. 13-3402.

Respectfully submitted,

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VERSION WITH MARKINGS TO SHOW CHANGES MADE

Replace the paragraph beginning at page 5, line 4, with the following:

Spectroscopic evaluations of the NIST-1 glass were performed to determine the cross relaxation coefficient of the Yb-Er energy transfer mechanism. The cross relaxation efficiency, η, of ytterbium to erbium ion in the glass was estimated by the inventors to be given by,

$$\eta = 1 - \tau_{Yb\text{-}Er}/\tau_{Yb}$$

where $\tau_{Yb\text{-}Er}$ is the measured lifetime of the Yb^{3+} $^2F_{5/2}$ level in a codoped sample with Er (measured at 1.79×10^{-3} seconds) and τ_{Yb} is the measured lifetime of Yb^{3+} $^2F_{5/2}$ level in a sample with no erbium (measured at 1.37×10^{-3} seconds). The value of η was thus calculated to be 0.87. Additional description of this modeling method, but applied to silicate glasses having greatly inferior laser properties, is provided in ~~the SPIE article provided as Paper E in the attached Appendix~~ *"Rigorous Scalar Modeling of Er and Er/Yb-doped Waveguide Lasers" (Veasey, Gary, Amin)* which is incorporated by reference.

Replace the paragraph beginning at page 14, line 3, with the following:

Another embodiment of the invention is directed to modifying or tuning the wavelengths of a waveguide or waveguides in a substrate. This can be done by heating of the substrate which will alter the wavelengths of the waveguides therein. Where the substrate containing waveguide(s) is part of a laser device, it was expected that the heating thereof would increase the wavelength of the laser due to expansion of the diffraction grating periodicity. What the inventors have discovered, however, is that for substrates containing solid state waveguides provided as channels in the substrate, as discussed above, heating has a fine tuning effect on altering the wavelength of the waveguide. Thus, for example, while semiconductor DFB lasers are increased in wavelength upon heating, the increase of wavelength upon heating of laser devices with waveguides according to this invention is significantly lower as a function of the temperature, e.g., the increase of wavelength as a function of temperature is roughly 15 times lower than that for semiconductor DFB lasers. The inventors have discovered that while heating expands the glass increasing the wavelength, the extent of increase is offset by the temperature effecting a decrease of the

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refractive index with temperature of the glass forming the waveguide(s). The theory behind this and experiments supporting it are described in the Journal of Non-Crystalline solids (JNCS) article ~~attached as Paper E in the Appendix~~ *"Rigorous Scalar Modeling of Er and Er/Yb-doped Waveguide Lasers"* (Veasey, Gary, Amin), particularly at page 14 and in Figure 14. According to the invention, therefore, the temperature control requirements for maintaining a stable wavelength are relaxed with the waveguides according to the invention, i.e., a variance in the temperature will not have as significant effect on the tuning, allowing finer tuning thereof.

Replace the paragraph beginning at page 16, line 7, with the following:

Waveguides prepared in accordance with any of the above descriptions, having multiple or single waveguides of the same or differing wavelengths, are useful in preparing lasers by providing the waveguide with a grating pattern. Examples of methods for producing lasers from waveguides of the type discussed above are provided in ~~the Papers A, B and C provided in the attached Appendix~~ *"Arrays of Distributed-Bragg-Reflector Waveguide Lasers at 1536 nm in YB/ER-co-doped Phosphate Glass"* (Veasey, Funk, Sanford, Hayden); *"170 mW eb at 1540 nm from an Erbium/Ytterbium Co-doped Glass Waveguide Laser"* (Funk, Veasey, Peters, Sanford, Hayden); and *"Ion-exchanged Er3+/YB3+ Glass Waveguide Lasers in Silicate Glasses"* (Peters, Veasey, Funk, Sanford, Houde-Walter, Hayden), which are incorporated herein by reference. These references also discuss methods generally applicable to production of waveguides and those teachings are additionally incorporated by reference herein. In general, lasers are fabricated from the waveguides by providing a reflecting element at both ends of the waveguide. The reflecting elements can be those known in the art. Included as embodiments are waveguides having optically polished ends provided with mirrors on both ends. An additional preferred embodiment, is providing the waveguide with a diffraction grating on one end of the waveguide. In a preferred embodiment, the grating is provided by etching onto the glass substrate containing the waveguide(s). One preferred type of grating is a DBR grating as known in the art. Such gratings are advantageous because they provide a narrow reflection line and thus provide a laser with a narrower wavelength.

Replace the paragraph beginning at page 19, line 4, with the following:

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Another embodiment is directed to segment having forty laser waveguides organized in eight sets. The segments may be processed, for example, according to one of the methods described in ~~Paper A, Paper B, and/or Paper C of the Appendix~~ *"Arrays of Distributed-Bragg-Reflector Waveguide Lasers at 1536 nm in YB/ER-co-doped Phosphate Glass"* (Veasey, Funk, Sanford, Hayden); *"170 mW eb at 1540 nm from an Erbium/Ytterbium Co-doped Glass Waveguide Laser"* (Funk, Veasey, Peters, Sanford, Hayden); and/or *"Ion-exchanged Er3+/YB3+ Glass Waveguide Lasers in Silicate Glasses"* (Peters, Veasey, Funk, Sanford, Houde-Walter, Hayden), to form a plurality of sets (e.g., in one embodiment, each set has five waveguides; and in another embodiment, each set is used such that one waveguide is used, and the other four provide redundancy in case one or more do not function properly). In this embodiment, each set is overlaid with a diffraction Bragg reflector (DBR) which forms one mirror of a laser, and each DBR is fabricated to a different spacing designed to resonate at a different output wavelength. In one embodiment, only eight of the forty waveguides are used for eight respective lasers; the others are provided for redundancy. Thus, the DBR for one set is designed such that all five waveguides of that set will lase at the same wavelength, and any one of these waveguides can be used as the laser for the desired wavelength of that set. However, each of the DBRs are designed for a different output wavelength. Thus the segment is designed to provide eight lasing waveguides each outputting light at one of eight predetermined wavelengths that are tuned by the eight DBRs. In one embodiment, an input mirror (e.g., a multi-layer dielectric mirror) is deposited on an end face of segment opposite the DBRs. In other embodiments, an external mirror is placed against that face to provide the feedback function desired for lasing and the pump-light-launching function. The input mirror is designed to transmit as much light as possible at the pump wavelength (in one embodiment, 0.98 micrometers), while reflecting as much light as possible at the output wavelength (in one embodiment, a selected wavelength near 1.54 micrometers as tuned by the corresponding to the DBR). In one embodiment, the segment is used in a communications system that uses dense wavelength-division multiplexing (DWDM), wherein, for example, forty different wavelengths are each modulated to carry a different channel of information, and then all forty channels are passed on a single optic fiber. In one such embodiment, each channel's wavelength differs from the next channel's wavelength by 0.8

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nanometers. Thus, for example, a segment could be designed to output laser light at wavelengths of 1.5360, 1.5368, 1.5376, 1.5384, 1.5400, 1.5408 and 1.5416 micrometers. Other segments of a system could be designed to lase at eight other channel wavelengths. Thus, a forty-channel system only needs five such different part numbers (i.e., unique part designs), rather than forty different part numbers in conventional approaches.

Replace the paragraph beginning at page 26, line 26, with the following:

To test the Yb/Er-codoped lasers, we typically pumped the waveguides using a tunable Ti:Al$_2$O$_3$ laser. Figure 1 shows a schematic of the laser measurement setup. Placing broadband dielectric mirrors on the polished waveguide end faces formed the laser cavities. The mirrors were held in place by small spring clips with index matching oil between the end facet and the mirror. The pump laser light was launched through one of the mirrors with a 4X microscope objective. The laser output and unabsorbed pump light were collimated with a 16X microscope objective and separated using filters. The mirror through which the pump light was launched had a reflectance of >99.9 % and 15 % at 1540 and 960 nm, respectively. The output coupler had a reflectance of 80 % at 1540 nm and 15 % at 960 nm. Neither the waveguide length nor the cavity output couplings were optimized. Additional information for this example can be found in the JNCS article ~~provided as Paper D in the attached Appendix~~ _"Rigorous Scalar Modeling of Er and Er/Yb-doped Waveguide Lasers"_ (Veasey, Gary, Amin).

Replace the paragraph beginning at page 31, line 22, with the following:

Before the DBR grating was formed by transferring the photoresist pattern into the glass by Ar-ion sputtering, 40 nm of Cr was deposited on the surface with the specimen inclined 60° to the electron-beam evaporation source. Mounting the specimen in this way causes Cr to accumulate only on the tops of the grating lines and not in the grooves, thus providing a durable etch mask. The grating was etched in the glass for 20 minutes using a reactive ion etching system with a 6.67 Pa (50 mTorr) Ar-ion plasma. The low-pressure plasma created a large self-bias voltage of 1700 V when running at 365 W of coupled power with frequency 13.5 MHZ. The electrode spacing was 3.2 cm. After etching, the sample was cleaned ultrasonically in photoresist

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stripper at 85°C. Fig. 1 of ~~Paper D in the Appendix~~ *"Rigorous Scalar Modeling of Er and Er/Yb-doped Waveguide Lasers"* (Veasey, Gary, Amin) is an illustration of the completed DBR laser array.

Replace the paragraph beginning at page 32, line 3, with the following:

The waveguide laser cavities were formed by placing a thin, highly reflecting (R=99.9% at 1540 nm, R=15% at 997 nm) dielectric mirror on the pump input facet. The mirror was held in place by a spring clip, and index-matching fluid was used between the mirror and the waveguide facet. The DBR grating was used as the laser output coupler. We tested the laser by coupling light from a $Ti-Al_2O_2$ laser turned to a wavelength of 977 nm using a 4x objective lens with a numerical aperture of 0.1. The launching efficiency was estimated to be between 65 and 71 percent. To determine the launching efficiency we measured the Fresnel reflectance of the input mirror, the loss of the launching objective, and the excess coupling loss. Fig. 10 of ~~Paper D in the Appendix~~ *"Rigorous Scalar Modeling of Er and Er/Yb-doped Waveguide Lasers"* (Veasey, Gary, Amin) shows the laser output power as a function of launched pump power and the spectrum of the laser. The waveguide diffusion aperture for this waveguide was 8 μm. The slope efficiency as a function of launched pump power is calculated to by 26 percent when we take the coupling factor to be 71 percent.

Replace the paragraph beginning at page 32, line 25, with the following:

To investigate the longitudinal mode structure of the laser we coupled the laser output into an optical fiber scanning Fabry-Perot interferometer with a free spectral range of 124 GHz. Fig. 11 of ~~Paper D in the Appendix~~ *"Rigorous Scalar Modeling of Er and Er/Yb-doped Waveguide Lasers"* (Veasey, Gary, Amin) shows that the laser operated on a single longitudinal mode when the coupled pump power did not exceed 300 mW. The laser was robustly single frequency with TE polarization, and no mode hopping was observed. The inset in Fig. 11 shows that a second longitudinal mode appeared when coupled pump power exceeded 300 mW. In this pump regime, the laser was unstable and exhibited mode hopping, single-frequency operation, and dual-frequency operations. By measuring the frequency spacing between the longitudinal

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modes we determined that the physical length of the laser cavity was 1.4 cm.

Replace the paragraph beginning at page 33, line 5, with the following:

We measured the linewidth of the laser using a conventional self-heterodyne configuration with a 75 MHZ frequency shift. The path length difference between the two arms was 10 km corresponding to linewidth resolution limit of 30 kHz for a gaussian line shape. Optical isolations were used in both arms to prevent optical linewidth narrowing due to feedback; however, the output end of the laser was not beveled. Fig. 12 of ~~Paper D in the Appendix~~ *"Rigorous Scalar Modeling of Er and Er/Yb-doped Waveguide Lasers"* (Veasey, Gary, Amin) shows the self-heterodyne spectrum. The laser linewidth we obtained from this measurement was 500 kHz.

Replace the paragraph beginning at page 33, line 12, with the following:

Finally, we measured the laser wavelengths of other waveguides on the chip using an automatic spectrum analyzer with a resolution of 0.1 nm. Seven of the eleven waveguides on the chip exhibited laser oscillation. The waveguides formed through the smaller apertures did not achieve threshold because the smaller mode volumes caused a reduction of the gain such that the 45 percent transmittance loss of grating could not be overcome. Fig. A5 in ~~Paper A of the Appendix~~ *"Arrays of Distributed-Bragg-Reflector Waveguide Lasers at 1536 nm in YB/ER-co-doped Phosphate Glass"* (Veasey, Funk, Sanford, Hayden) shows the change in wavelength trend as we scanned the waveguides. The wavelength increases as the diffusion aperture width increases, which is consistent with increasing effective index as the aperture width increases.

Replace the paragraph beginning at page 35, line 11, with the following:

In another embodiment, the refractive index as a function of position within the exchanged sample was analyzed using a refractive near-field scanning method. Fig. B1 in ~~Paper B of the Appendix~~ *"170 mW eb at 1540 nm from an Erbium/Ytterbium Co-doped Glass Waveguide Laser"* (Funk, Veasey, Peters, Sanford, Hayden) shows the index depth profile at the center of the waveguide formed with the 6.5 μm mask aperture for a wavelength of 633 nm. This

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method allows the relative position and absolute index values to be determined with an accuracy of 0.7 µm and 0.001, respectively.

Replace the paragraph beginning at page 35, line 26, with the following:

In another embodiment, the device was pumped with a Ti^{3+} sapphire laser. The waveguide laser cavities were formed by placing thin dielectric mirrors on the polished waveguide end faces. The mirrors were held in place by small spring clips, and index matching oil was used between the mirror and waveguide end faces to reduce losses. The pump laser was launched through one of the mirrors with a 4X microscope objective. The laser output and unabsorbed pump were collimated with a 16X microscope objective and separated using filters. The laser cavity was 20 mm in length. The mirror through which the pump was launched had reflectivities of >99.9% and 15% at 1536 and 980 nm, respectively. The output coupler had a reflectivity of 80% at 1536 nm and transmitted 85% of the incident pump power. Neither the waveguide length nor the cavity output coupling has been optimized. The launching efficiency was estimated to be ≤ 71%, including losses due to the transmission of the input mirror and launching objective. The laser output power characteristics for two different pump wavelengths are illustrated in Fig. B2 of ~~Paper B in the Appendix~~ *"170 mW eb at 1540 nm from an Erbium/Ytterbium Co-doped Glass Waveguide Laser"* (Funk, Veasey, Peters, Sanford, Hayden). When pumped at 979 nm, the launched pump power threshold was 51 mW. A maximum output power of 168 mW was obtained for 611 mW of launched 979 nm pump power. A lower threshold could be obtained by turning the pump laser off of the Yb^{3-} absorption peak. For a pump wavelength of 960 nm, the threshold was 23 mW. The slope efficiency for both pump wavelengths was ~ 28%.

Replace the paragraph beginning at page 36, line 14, with the following:

Using the broad-band cavity described above, the Er^{3+}/Yb^{3+} laser usually operated at several wavelengths simultaneously. A typical laser spectrum showing simultaneous operation at 1536.0, 1540.7 and 1544.8 nm is depicted in Fig. B3 of ~~Paper B in the Appendix~~ *"170 mW eb at 1540 nm from an Erbium/Ytterbium Co-doped Glass Waveguide Laser"* (Funk, Veasey, Peters,

<u>Sanford, Hayden</u>). The wavelength(s) of operation could be shifted by passing some of the collimated 1.5 μm laser output through a prism and reflecting it back through the prism and into the waveguide using a dielectric mirror. This formed a weakly-coupled, external cavity. By rotating the prism, it was possible to produce wavelengths ranging from 1536 to 1595 nm.

Replace the paragraph beginning at page 36, line 22, with the following:

A common feature of many three-level rare-earth lasers is sustained relaxation oscillations which can be caused by small fluctuations in the pump laser power. Fluctuations in output power at frequencies ranging from ~ 0.5 to 1.5 MHZ were observed in this laser. The amplitude of the fluctuations decreased with pump power. Figure ~~in B4 Paper B of the Appendix~~ B4 in "*170 mW eb at 1540 nm from an Erbium/Ytterbium Co-doped Glass Waveguide Laser*" (Funk, Veasey, Peters, Sanford, Hayden) shows the output power as a function of time for pump power levels just above threshold and 9.4 times threshold. At the low pump power, the output power fluctuations of ~ 30% (peak to peak) of the average power were observed. At the high pump power, the fluctuations decreased to ~ 5% (peak to peak) of the average power. The Ti^{3+}:sapphire pump laser exhibited output power fluctuations of ~ 2-3%. Using a diode laser as the pump source should result in much quieter operation of the Er^{3+} laser.

Replace the paragraph beginning at page 39, line 10, with the following:

The laser performance was investigated as a function of device length as well as output coupler reflectance. Figure C1 in ~~Paper C of the Appendix~~ "*Ion-exchanged Er3+/YB3+ Glass Waveguide Lasers in Silicate Glasses*" (Peters, Veasey, Funk, Sanford, Houde-Walter, Hayden) shows a plot of laser signal power vs. launched pump power for two different output couplers, for a 1.68 cm long device fabricated in the glass with 5 Yb^{3+} per Er^{3+} ion. The slope efficiencies and laser thresholds were determined by fitting a line to the laser data. The lowest threshold was achieved when using a 98% reflector as output coupler. This device lased with a launched pump power threshold of approximately 59 mW. The slope efficiency of this device was 2.0% with respect to launched pump power. The highest slope efficiency was realized with a 70% reflector used as an output coupler. In this case, a slope efficiency of 6.5% was achieved with a launched

pump power threshold of 86 mW. For a launched pump power of 398 mW, this laser produced 19.6 mW of output power.

Replace the paragraph beginning at page 39, line 22, with the following:

A plot of slope efficiency vs. output coupler reflectance for each host glass appears in Figure C2 of ~~Paper C of the attached Appendix~~ *"Ion-exchanged Er3+/YB3+ Glass Waveguide Lasers in Silicate Glasses"* (Peters, Veasey, Funk, Sanford, Houde-Walter, Hayden). Data for device lengths in each glass which were experimentally determined to give the highest slope efficiency are plotted. Highest slope efficiency performance in each host is also compared in Table 1.

Page 40, after line 16, insert the following new section:

Brief Description of the Drawings

Figure 1 shows a schematic of the laser measurement setup.

Figure 2 shows an embodiment of the fabrication of a single-frequency 1.32-1.4 um laser in Nd-doped phosphate glass fused to La-doped glass.   B

Delete all the pages which appear as Appendices A-E of the disclosure following the Abstract.